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Abstract

In many developing countries, efforts are being made to encourage more efficient energy choices to lessen adverse effects on health and the environment. This study examined the relationship among fuel options and assessed the determinants of household energy choices for Ibadan, Nigeria. Data collected from 180 respondents using multistage sampling procedure were analysed with bivariate probit and logit regression models. Firewood and charcoal were found to be in use as substitute cooking fuels to LPG while electricity was used as its complement. Improved economic state of households was associated with the use of clean energy sources. Households with large number of members had to settle for less clean fuel types because of low per capita resource availability while education assisted in making better fuel choices for cooking. The study recommends policies aimed at growing national income and improving citizens' welfare. Education-for-all campaigns should be intensified and national education projects scaled up for improved access. Rural areas also need targeted development so that the inhabitants can seek alternatives to traditional fuels.

Keywords: Biomass; clean energy; household welfare; sustainable environment

JEL Classification: I31, O13, Q40, Q56

1. Introduction

1.1 Background

Energy is essential for human activities and is indeed critical to social and economic development (Bisu *et al.* 2016). Nigeria is richly blessed with abundant resources to provide households with biomass and other modern energy sources for domestic use (Ogwumike *et al.* 2014). At present, energy is the mainstay of Nigeria's economic growth and development and oil and gas have continued to contribute over 70 per cent of Nigeria's federal revenue on which national development programmes depend (Oyedepo 2012).

Globally, more than 3 billion people make use of biomass energy sources such as woods, charcoal, animal dung and crop residue and about 1 billion are dependent on kerosene lamps and similar traditional devices for lighting (WHO 2016). These sources and associated devices are especially widely used in the rural communities of many developing countries because of less access to modern and clean energy sources (Bamiro & Ogunjobi 2015). Solid fuels are usually responsible for pollution of the environment and consequent harmful effect on human health in their usage for cooking, lighting and heating (Winijkul & Bond 2015). Cooking with solid fuels is responsible for 6 per cent of global black carbon emissions and 1.2 per cent CO_2 emissions (UNEP 2019). Materials from combustion of biomass and kerosene pose serious health and climatic risks because of their toxic and carbonaceous particulate properties, respectively (Lamberg *et al.* 2011; Lam *et al.* 2012) with the ensuing air pollution fingered as contributing factor to respiratory health problems in women and children (Tabaku *et al.* 2011; WHO 2016). Kerosene lamps, which use traditional fuel sources, contribute to greenhouse gas (GHG) CO_2 emissions and also worsen climate change situation (Tedsen 2013). The use of traditional cookstoves and consumption of woodfuel are more energy intensive, causing more environmental pollution but using appropriate and more efficient modern appliances could mitigate these problems considerably (Garland *et al.* 2017).

There are currently significant efforts at advocating for clean energy use, but this is inadequate in comparison to expanding global economy and increasing population, which underscores huge requirement for policy shift (Ouedraogo 2017; IEA 2019). For example, though there had been gains in access to electricity in sub-Saharan Africa (SSA) since 2013, 75 per cent of global population without access to electricity still live in the sub-region and the past gains are being wiped away by COVID-19 pandemic (IEA 2020). As far back as 2015, out of 3.04 billion people that did not have access to clean cooking fuel, about 800 million were from SSA (UNEP 2019).

This study is significant in several respects. Firstly, the type of fuel used by households has implications for the environment in terms of climate change impact through the greenhouse gas (GHG) emissions. Secondly, the health of the environment has direct bearing on the wellbeing of the inhabitants particularly the vulnerable: children, those with health challenges and the elderly. Finally, type of fuel being used is a pointer to the level of development. Assessment of the fuel type use in a developing country like Nigeria will showcase level of reliance on traditional energy types and the level of effort that will be needed in the drive for a sustainable environment.

2. Literature Review

Several studies have been conducted on energy choice and usage in Nigeria. These studies are diverse in both scope and the methodologies adopted. Ozoh *et al.* (2018) examined household cooking fuel use in Lagos, Nigeria. Kerosene was the most frequently used but respondents were willing to transit to LPG if issues of safety and cost are taken care of. Educational level, increased income and age were found to positively influence cleaner energy use. Bisu *et al.* (2016) examined the determinants of the use of traditional energy sources in Bauchi metropolis using regression analysis. Results showed that biomass was still being primarily and widely used for cooking while the use of LPG has also improved. The pattern of energy use followed fuel stacking hypothesis rather than energy ladder hypothesis. Education level, income, household size, location, dwelling ownership status, availability and affordability were the factors affecting household cooking energy choice.

Bamiro & Ogunjobi (2015) adopted multinomial logit and tobit regression models to assess the determinants of fuel choice and energy consumption for Ogun State. Prices of fuel and family size significantly influenced choice of fuels. Aya *et al.* (2014) employed Ordinary Least Square (OLS) procedure to determine household interfuel substitution and concluded that household income level affects the use of kerosene for cooking. Households tend to switch to multiple fuel use strategy as income increased instead of completely switching from traditional to modern energy sources. Baiyegunhi & Hassan (2014) researched the rural household fuel choice determinants in Kaduna, Nigeria using multinomial logit model. Fuel stacking was found to be the realistic description of the energy use in the study area as fuelwood was being used along other fuel types. Age of household head, educational attainment, household size, duration of cooking, income, dwelling unit type and fuelwood price were the most important factors dictating cooking fuel use. Adepoju *et al.* (2012) used the logit model to assess the factors influencing choice of energy by rural households in Ogun state, Nigeria. Largest proportion of the respondents were found to use kerosene for both cooking and lighting. Gender was also found to influence fuel wood choice and households headed by non-literates had higher likelihood of choosing charcoal. Choices of kerosene oil and electricity were found to be influenced by proximity.

Elsewhere in Africa, Ateba *et al.* (2018) examined fuel energy choice in Gauteng and North West, South Africa. High-income households tend to use more cleaner energy sources for cooking and heating. Household size, educational level of household members and their gender influenced the kind of energy source used for cooking, lighting and heating. Olang *et al.* (2018) studied the relationship between household lighting and cooking fuel choice and multidimensional energy poverty in Kenya's low-income households. Appliance type and location were the main factors affecting energy choice. There was general willingness to use modern energy sources notwithstanding the state of energy poverty. Basu *et al.* (2016) noted that biomass energy sources, mainly in form of wood and charcoal, took up to 90 per cent of energy use for cooking in Kenya while kerosene was the fuel for lighting. Mwaura *et al.* (2014) applied multinomial probit model to the Uganda National Household Survey (UNHS) data. Residence of respondents, household size, location and educational level were the important factors explaining choice of cooking energy source. Very small percentage of the households utilised modern energy sources for cooking. Nlom & Karimov (2014) used ordered probit model to investigate fuel choices among Cameroonian households. Results showed that fuel choices were determined by own and alternatives' prices, household income, age and educational attainment of heads while shift from traditional biomass energy to cleaner energy types was in early stages. Firewood was found to be mostly in use and there's need for increase in household income for effective transition from traditional biomass sources to cleaner energy types.

Outside Africa, Soltani *et al.* (2019) examined demographic characteristics affecting energy choice and consumption in Mahabad City in Iran. Results of the logistic regression showed that location, household size and income were the factors affecting energy choice. Bhatta *et al.* (2018) also showed the importance of household income household transition to modern fuels in Nepal while family size, location, education had significant effect on household fuel choice behaviour. Giri & Goswami (2017) studied the determinants of household energy choice for lighting in Nepal using multinomial logit regression. Income, gender, location, education level of household head, family size, population of dependents were the factors influencing energy choice.

This study attempts to bridge the knowledge gap in literature by paying special attention to the issue of fuel substitution and complementation among fuel alternatives. A good number of studies have examined fuel transition and factors affecting household energy choice with particular attention to household characteristics as well as external conditions like price with the conclusion that household energy use follows fuel stacking pattern rather than energy ladder hypothesis. However, very few attempts have been made in understanding the relationship among the fuels for household use. Moreover, as observed by Ogwumike *et. al.* (2014), there is still room for more studies on energy types and how they affect welfare of households in Nigeria. In view of these observations, this study seeks to assess the relationships among energy types and examine factors affecting household energy choices in Ibadan, a characteristic developing country city.

3. Materials and Methods

3.1 Study area

The study was conducted in Ibadan (lat. $7^0$32′N, long. $3^0$54′E) the largest truly indigenous urban centre in Africa south of the Sahara. The city is located near the forest grassland boundary of South-western Nigeria and is approximately 150 kilometres North-east of Lagos, the commercial capital of Nigeria. It has an estimated total land area of about 130.50 sq. km. Ibadan is usually referred to as the black colossus with characteristic blend of rural and urban settings, thus making it very significant and relevant within a developing country context. There are eleven local governments areas (LGAs) in Ibadan which represent the administrative units. Five (5) LGAs namely Ibadan North, Ibadan Northeast, Ibadan Northwest, Ibadan Southeast and Ibadan Southwest are in the urban area while six (6) Akinyele, Egbeda, Ido, Lagelu, Ona Ara and Oluyole, are in the peri-urban/rural areas.

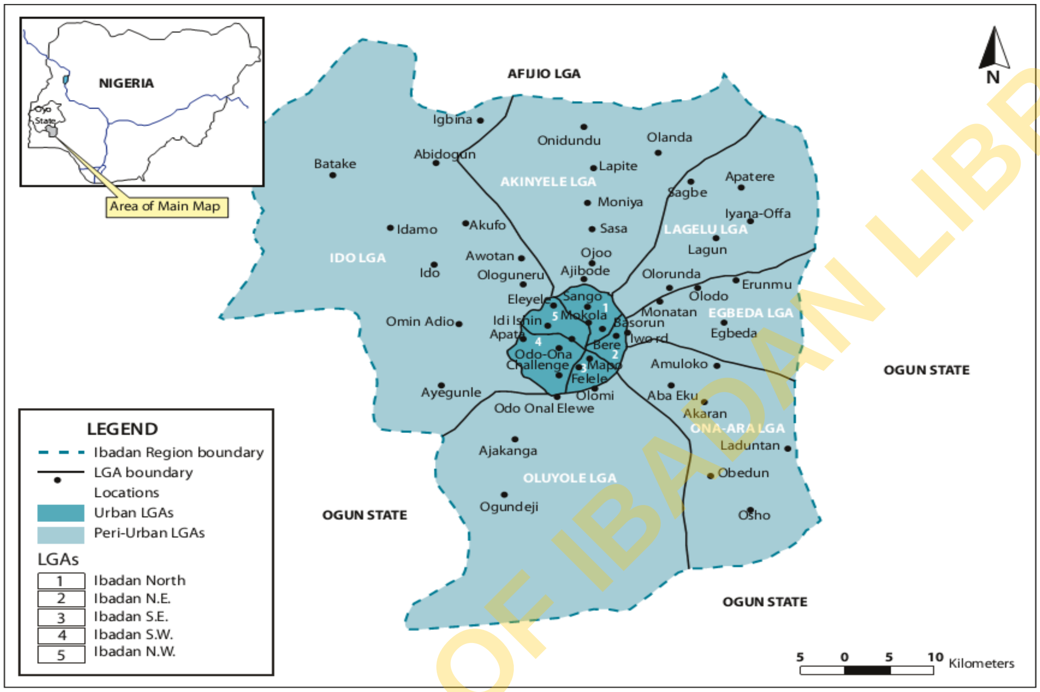

Fig. 1. Map of Ibadan showing urban and peri-urban/rural LGAs

3.2 Data collection and sampling

Four-stage sampling procedure was used in this study. The first stage involved stratification of the study area into urban and peri-urban/rural strata. In the second stage, two LGAs were randomly selected from each of the strata: Ibadan Southeast and Ibadan Southwest LGAs from urban stratum and Ona-Ara and Oluyole LGAs from peri-urban/rural stratum. In the third stage, three wards/areas were selected randomly from each LGA, making a total of twelve (12) wards/areas. The fourth stage involved random selection of an average of fifteen households from the wards/areas depending on size, to get a total of one hundred and eighty respondents. Questionnaires were distributed in Felele, Challenge, Elekuro, Iyaganku, Ring Road, Oluyole, Idi Osan, Idi Ayunre, Muslim area, Oritamerin Tioya, among others. Data were collected from households on location, fuel type use, distance to fuel source, energy device complexity, types of dwellings, poverty status, years of education and household income, among others.

3.3 Model specifications

Two models were used to analyse the data of this study. These are bivariate probit regression and logit regression models. Their descriptions and specifications are given in this sub-section.

3.3.1 Bivariate probit regression

Bivariate probit regression analysis was used to determine the nature of the relationship existing among the various fuel types available for cooking and lighting. Biprobit regression is a technique that estimates a single regression model with two outcome variables in the presence of more than one predictor variable. Greene & Henser (2009) expressed bivariate probit model to be a natural extension of the probit model with more than one equation that could be with or without correlated disturbances. Accordingly, the general specification for a two-equation model could be written as,

$$y_1^* = \gamma_1' x_1 + \varepsilon_1, \quad y_1 = 1(y_1^* > 0),$$
$$y_2^* = \gamma_2' x_2 + \varepsilon_2, \quad y_2 = 1(y_2^* > 0), \quad \ldots (1)$$
$$E[\varepsilon_1 \mid x_1, x_2] = E[\varepsilon_2 \mid x_1, x_2] = 0,$$
$$Var[\varepsilon_1 \mid x_1, x_2] = Var[\varepsilon_2 \mid x_1, x_2] = 1,$$
$$Cov[\varepsilon_1, \varepsilon_2 \mid x_1, x_2] = \rho$$

The normal cumulative density function is denoted from the probability

$$\text{Prob}(X_1 < x_1, X_2 < x_2) = \int_{-\infty}^{x_2} \int_{-\infty}^{x_1} \phi_2(z_1, z_2, \rho)\, dz_1 dz_2 \quad \ldots (2)$$

as $\phi_2(x_1, x_2, \rho)$. Thus, the density is given as

$$\phi_2(x_1, x_2, \rho) = \frac{\exp\left[-\frac{1}{2}\frac{x_1^2 + x_2^2 - 2\rho x_1 x_2}{(1-\rho^2)}\right]}{2\pi\sqrt{1-\rho^2}} \quad \ldots (3)$$

The probability for the likelihood function is

$$\text{Prob}(Y_{i1} = y_{i1}, Y_{i2} = y_{i2} \mid x_{i1}, x_{i2}) = \Phi_2(w_{i1}.w_{i2}, \rho_i *) \quad \ldots (4)$$

to give a log-likelihood of

$$\ln L = \sum_{i=1}^{n} \ln\Phi_2(w_{i1}.w_{i2}, \rho_i *) \quad \ldots (5)$$
$$= \sum_{i=1}^{n} \ln\Phi_{i2}$$

which becomes the following after reduction,

$$\frac{\partial \ln L}{\partial \gamma_j} = \sum_{i=1}^{n} \left(\frac{q_{ij} g_{ij}}{\Phi_{i2}}\right) x_{ij}, j = 1,2, \quad \ldots (6)$$
$$\frac{\partial \ln L}{\partial \rho} = \sum_{i=1}^{n} \frac{q_{i1} q_{i1} \phi_2}{\Phi_{i2}},$$

where

$$g_{i1} = \phi_2(w_{i1})\Phi\left[\frac{w_{i2}-\rho w_{i1}}{\sqrt{1-\rho^2}}\right] \quad \ldots(7)$$

g_{i2} is obtained by reversing the subscripts 1 and 2 in g_{i1}.

For this study, usage of LPG and kerosene were adopted as dependent variables for the cooking fuel regression because they were found to be the two mostly used fuels for cooking. Similar case was obtainable for lighting fuel where petrol and kerosene were mostly in use.

The biprobit models specified are as follow:

$$Pc_i = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \ldots + \beta_7X_7 + \beta_8X_8 + Df_i + Dch_i + De_i + \varepsilon_i \quad \ldots(8)$$

$$P_{Li} = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \ldots + \beta_7X_7 + \beta_8X_8 + Dk_i + Db_i + Dcd_i + \varepsilon_i \quad \ldots(9)$$

where,

Pc_i = Probability of using i^{th} fuel for cooking

P_{Li} = Probability of using i^{th} fuel for lighting

and,

X_1 = Sex of respondents; X_2 =Age of respondents; X_3 = Years of education
X_4 = Location of respondents; X_5 = Marital status of respondents; X_6 = Household size
X_7 =Monthly income of respondents; X_8 = Type of dwelling unit
Df_i = Firewood; Dch_i = Charcoal; De_i = Electricity; Dk_i = Kerosene; Db_i = Battery;
Dcd_i = Candle; βs = parameters to be estimated; ε_i = error terms

3.3.2 Logit regression model

Logit was adopted for the determination of factors affecting types of fuel being used. Logit regression is similar to probit but differs in the type of Cumulative Distribution Function (CDF). Modifying from Stock & Watson (2009), the logit model for this study can be specified as,

$$P_k\,(Y=1/X_1, X_2, \ldots, X_n) = \frac{1}{1+e^{-(\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n)}} \quad \ldots(10)$$

from vector equation: $$P_k = \frac{1}{1+e^{-(\beta_0+\sum\beta_iX_i)}} \quad \ldots(11)$$

where,

P_k= Probability of using energy source k
e = exponential function
β_0 = constant β_i = vector of coefficients
X_i = vector of explanatory variables,

and,

X_1 = Sex of respondent; X_2 = Age of respondent; X_3 = Household size
X_4 = Monthly income; X_5 = Years of education; X_6 = Location of respondent

X_7 = Type of dwelling unit; X_8 = Poverty status; X_9 = Closeness to fuel source
X_{10} = Complexity of device.

3.3.3 Estimation of poverty status

Relative poverty measure was used in estimating poverty status of the households. Households were disaggregated into different poverty status categories using the poverty line. The poverty line was computed as two-third of the mean per capital household expenditure (MPCHHE) of all members of the sampled households. The calculation of the MPCHHE was done in two steps. Firstly, the amount being spent on food and other basic needs by each household was divided by the household size to get the per capita household expenditure. The second step involved finding the mean of the initial values by dividing the total with the number of sampled households. The poverty line is two-third of this final figure. Any household above this amount was considered non-poor while anybody below it was considered poor.

4. Results and Discussion

4.1 Socioeconomic and energy use characteristics of respondents

The socio-economic characteristics of the respondents are presented in Table 1. Sex distribution of respondents revealed that male-headed households dominated the study area while more than half of these heads had considerable level of education. The mean age of the respondents was 44.7 years and respondents within the age range of 31-40 and 41-50 years had the highest percentages of 28.3 per cent and 27.8 per cent, respectively. Thus, majority of the respondents were adults and higher proportion of the sampled household heads were in their active and productive years. Also, 70.6 per cent of the respondents were married, 62.8 per cent had family size of 4-6 persons and the mean household size in the study area was 5 persons per household. Marital status of household heads and the number of household members could determine household energy use. For instance, households with married heads tend to have more energy requirements while large size could predispose households to using cheaper options, especially in the presence of low income. Incidentally, income distribution revealed that 37.8 per cent of the respondents had monthly income within the range of ₦31,000- ₦50,000 ($86.1 - $138.9) while 26.7 per cent had monthly income of ₦30,000 ($83.3) or lower. The mean monthly income of the respondents was ₦57,222 ($159.0). In effect, more than three-fifths of the respondents constituted the two lowest income categories.

Table 1: Distribution of respondents by socioeconomic characteristics

Variable	Description	Frequency	Percentage
Sex	Male	113	62.8
	Female	67	37.2
Age	≤30	27	15.0
	31-40	51	28.3
	41-50	50	27.8
	51-60	37	20.6
	61-70	15	8.3
Level of education	No formal education	18	10.0
	Primary school	18	10.0
	Secondary school	45	25.0
	NCE/OND/HND	67	37.2
	Degree holders	21	11.7
	PGDE/ MSc/Phd	11	6.1
Marital status	Single	31	17.2
	Married	127	70.6
	Divorced	9	5.0
	Widowed	13	7.2
Household size	1-3	38	21.1
	4-6	113	62.8
	7-9	19	10.5
	>9	10	5.6
Monthly Income (₦)	≤30000	48	26.67
	31000-50000	68	37.78
	51000-70000	32	17.78
	71000-90000	15	8.33
	>90000	17	9.44
	Total	**180**	**100.0**

Field Survey (2017) Exchange rate: $1= ₦360

The distribution of poverty status of respondents is presented in Table 2. Using a poverty line of ₦9,323.80 ($25.9), 45.0 per cent of the respondents were found to be poor. Thus, there were more non-poor than poor people in the study area. Table 3 shows the distribution of major household fuels used in the household for cooking and lighting. Approximately half of the respondents were using LPG, 31.3 per cent utilized kerosene while 10.6 per cent used firewood for cooking. None of the respondents used charcoal as major cooking fuel. With respect to lighting, 51.7 per cent of the respondents used petrol, 20.6 per cent used electricity while 15 per cent used kerosene as their major sources of lighting fuel. Less than 2 per cent each used batteries and candlesticks as major lighting sources.

Table 2: Distribution of respondents by poverty status

Poverty status	Frequency	Percentage
Poor	81	45.0
Non-poor	99	55.0
Total	**180**	**100**

Table 3: Distribution of respondents by major household cooking and lighting fuel types

Cooking fuel			Lighting fuel		
Type	**Frequency**	**Percent**	**Type**	**Frequency**	**Percent**
Firewood	19	10.6	Battery	21	1.7
Charcoal	0	0.00	Petrol	93	51.7
Kerosene	56	32.4	Kerosene	27	15.0
LPG	91	50.8	Candle	2	1.0
Electricity	13	7.2	Electricity	37	20.6
Total	**180**	**100**	**Total**	**180**	**100**

Field Survey (2017)

4.2 Relationships among categories of fuel options

4.2.1 Cooking fuels

Liquified Petroleum Gas **(**LPG) and kerosene were the two mostly used fuel options in the study area as both were used as main household fuels by 82.12 per cent of the respondents. This gives an insight that the other fuel types were either complements or substitutes. The results for the cooking fuels are presented in Table 4. In the LPG category, both firewood ($p<0.05$) and charcoal ($p<0.01$) uses had significant negative relationship with LPG use while electricity ($p<0.10$) had positive relationship. The changes in the probability of LPG usage as a result of increase in firewood, charcoal and electricity usage were -0.9 per cent, -9.9 per cent and +12.1 per cent, respectively. This means that both firewood and charcoal were used as substitutes to LPG while electricity was used as complement. Those that used LPG also consumed electricity along, both being clean household fuels with the implication that any household that did not fall within this 'privileged' caucus automatically settled for biomass energy sources. As regards other variables, a year increase in education increased probability of using LPG by 2.1 per cent. The change in LPG use with respect to increase in household income was infinitesimal, though positive also.

Kerosene seemed to be a standalone energy source as far as cooking is concerned since its use had no relationship with the use of other energy sources. Rather, its use was affected by education, household size and type of dwelling. In effect, a unit increase in household size increased the probability of kerosene usage by 1.2 per cent while staying in a traditional household setting increased the probability of using kerosene by 19.5 per cent. Traditional house setting is a common characteristic of the rural area where the use of less efficient energy sources is rife. By contrast, a year increase in education reduces probability of kerosene usage by 2.4 per cent which means that educated folks were less likely to use kerosene for cooking. The result is in line with Aya *et al.* (2014).

4.2.2 Lighting fuels

Results shown in Table 5 revealed that age and staying in single room/self-contained dwelling unit had negative relationship with the probability of using petrol for lighting while income had positive relationship with petrol use. This means that the older the respondents, the lower the probability of using petrol as a lighting source probably within a precautionary context. Also, households living in improved housing units (flats) tend to use petrol less for lighting probably because of better access to cleaner lighting source such as electricity. Living in a single room/self-contain apartment reduced the probability of using petrol for lighting by 2.7 per cent.

Further results on lighting energy types revealed that years of education and household income had positive relationships with probability of electricity usage while staying in rural area, being married and staying in traditional housing units were negatively related to probability of using electricity for lighting. A year increase in duration of education increased the probability of using electricity by 1.3 per cent while residence in rural areas, being married and residing in traditional house decreased the probability by 5.4 per cent, 0.9 per cent and 5.9 per cent, respectively. Educated people were much more informed of the consequences of using unclean fuels since they mostly reside in urban areas where there is access to clean fuel types. Positive effects of education on clean energy use is in accordance with Bhatta *et al.* (2018). The married used less electricity because of the need to balance between the cost of energy and other household responsibilities. Candle was being used as substitute to electricity. This seems to be an unsafe alternative because of bare fire involved.

Table 4: Parameter estimates of the relationships among cooking energy types

	Coef.	Std. Err.	z	dy/dx	Coef.	Std. Err.	z	dy/dx
	Liquefied Petroleum Gas (LPG)				Kerosene			
Sex								
Female	0.132	0.243	0.54	0.029	-0.085	0.232	-0.37	-0.046
Age	-0.024	0.016	-1.54	0.002	-0.010	0.013	-0.82	0.007
Years of education	0.065**	0.031	2.07	0.021	-0.067**	0.029	-2.32	-0.024
Location								
Rural	-0.115	0.249	-0.46	0.010	-0.054	0.245	-0.22	0.035
Marital status								
Married	0.050	0.287	0.17	-0.009	0.039	0.265	0.15	-0.015
Household size	0.010	0.091	0.11	-0.106	0.378***	0.099	3.84	0.012
Monthly income	1.78E-05**	7.20E-06	2.47	-1.25E-06	6.97E-06	4.82E-06	1.45	-5.51E-06
Type of dwelling								
Single room/Self con.	-0.322	0.275	-1.17	-0.046	0.107	0.268	0.40	0.105
Traditional	-0.503	0.490	-1.03	-0.214	0.891*	0.517	1.72	0.195
Energy type								
Firewood	-0.703**	0.290	-2.43	0.009	-0.133	0.296	-0.45	0.223
Charcoal	-0.866***	0.306	-2.83	-0.099	0.230	0.308	0.75	0.292
Electricity	0.490*	0.297	1.65	0.121	-0.362	0.256	-1.41	-0.175
Constant	0.122	0.838	0.15		-0.248	0.755	-0.33	
Log likelihood	**-154.254**							
Observation	**180**							
Wald chi^2(24)	**85.31**							
Prob>chi^2	**0.000**							

$^{***, **, *}$ *represent significance at 1%, 5% and 10% levels, respectively; dy/dx: marginal effects.*

Table 5: Parameter estimates of the relationships among lighting energy types

	Coef.	Std. Err.	z	dy/dx	Coef.	Std. Err.	z	dy/dx
	Petrol				Electricity			
Sex								
Female	-0.301	0.218	-1.38	-0.029	0.211	0.284	0.74	0.128
Age	-0.046***	0.014	-3.30	-0.001	-0.009	0.017	-0.54	0.016
Years of education	-0.019	0.027	-0.69	-0.006	0.062*	0.034	1.82	0.013
Location								
Rural	-0.010	0.229	-0.04	0.048	-0.548**	0.277	-1.98	-0.054
Marital status								
Married	-0.163	0.262	-0.62	0.037	-0.574*	0.337	-1.7	0.009
Household size	0.043	0.081	0.53	8.17E-03	-0.075	0.091	-0.83	-0.023
Monthly income	2.01e-05***	5.63E-06	3.57	-1.76E-06	3.11E-05***	9.51E-06	3.27	-4.01E-06
Type of dwelling								
Single room/ Self con.	-0.554**	0.252	-2.20	-0.027	0.086	0.313	0.27	0.203
Traditional	-0.618	0.406	-1.52	0.070	-0.903*	0.472	-1.91	0.059
Energy type								
Kerosene	0.338	0.260	1.3	0.005	0.110	0.315	0.35	-0.109
Battery	0.133	0.236	0.56	0.016	-0.123	0.284	-0.43	-0.060
Candle	-0.223	0.408	-0.55	0.094	-1.225**	0.485	-2.53	-0.044
Constant	1.513	0.737	2.05		0.270	0.922	0.29	
Log likelihood	**-163.83**							
Observation	**180**							
Wald $chi^2(24)$	**70.43**							
Prob>chi^2	**0.000**							

***, **, * *represent significance at 1%, 5% and 10% levels, respectively; dy/dx: marginal effects.*

4.3 Determinants of household energy choices

4.3.1 Cooking fuels

The results of logit regressions for cooking fuels used by the respondents (firewood, kerosene, LPG and electricity) are presented in Table 6. Charcoal was excluded from the choice categories because no household in the study area used it as a major cooking fuel. From the results, unit increase in age increased the probability of firewood use by 0.6 per cent but decreased probability of LPG and electricity use by 0.9 per cent and 0.7 per cent, respectively. Increase in household size by a member also increased the probability of firewood use by 4.7 per cent and kerosene use by 11.1 per cent. Negative effect of household size on cleaner energy use has been reported by Bamiro & Ogunjobi (2015). The marginal effect value for household income suggests that a unit increase in income increased the probability of LPG and electricity usage for cooking by 24.4 per cent and 29.5 per cent, respectively. The positive relationship is also true for education with LPG use as the probability of its use increased by 2.1 per cent in response to a year increase in education. In contrast, probability of firewood and kerosene usage decreased by 1.6 per cent and 2.2 per cent respectively, for a unit increase in education year. Residence in rural area increased the probability of firewood use by 17.1 per cent but reduced electricity use by 12.0 per cent, in comparison to living in urban location. Dwelling in traditional housing unit increased the probability of using kerosene for cooking by 21.9 per cent as compared to inhabiting improved housing unit.

From the foregoing, age was negatively associated with cleaner energy use in contrast to findings of Ozoh *et al.* (2018). This may be because of less-cosmopolitan nature of Ibadan where older people are still much more attached to cultural practices. Also, households with large members seemed to tilt more towards unclean fuel choices because of cost, with kerosene mostly in use for cooking. Furthermore, as household income increased, there tend to be a shift to clean and modern fuels. This is consistent in part with the ‘energy ladder’ theory. The characteristic is also true of educational attainment because of higher level of exposure. Rural areas seem to adopt biomass energy source because of poor access to clean energy types owing to low level of development.

4.3.2 Lighting fuels

Results presented in Table 7 shows that a unit increase in household income increased the likelihood of choice of petrol by 32.8 per cent and electricity by 22.0 per cent. Giri & Goswami (2017) had earlier pointed out that as income increases, the probability of electricity use for lighting increases. This is of course premised on access. Increase in household size by a member also increased the tendency of using kerosene by 3.8 percent. Higher poverty status was associated with increased probability of using kerosene by 23.1 per cent but linked with reduced likelihood of using electricity for lighting by 15.6 percent. This may be a fall out of affordability as noted in Ogwumike *et al.* (2014). Living in a single room/self-contain apartment increased the likelihood of using battery for lighting by 24.6 per cent but reduced the likelihood of using petrol by 16.6 per cent, relative to living in flat apartment. Inhabiting rural area reduced the probability of using battery for lighting by 15.3 per cent, relative to being in the urban area while having female household head increased the probability of using kerosene (15.3 per cent) and electricity (10.7%) for lighting, relative to having male as the head. Gender effect on lighting energy source has also been reported by Giri & Goswami (2017). Households headed by females tend to enjoy better resource allocation than those headed by males. Education did not dictate the use of any of the lighting options and petrol consumption reduced with age.

Table 6: Parameter estimates of the determinants of use of various energy types for cooking

	Coef.	s.e.	z	dy/dx	Coef.	s.e.	z	dy/dx	Coef.	s.e.	z	dy/dx	Coef.	s.e.	z	dy/dx
	Firewood				**Kerosene**				**Liquefied Petroleum Gas (LPG)**				**Electricity**			
Sex																
Female	0.051	0.437	0.12	0.007	-0.067	0.400	-0.17	-0.011	0.106	0.409	0.26	0.016	-0.036	0.398	-0.09	-0.006
Age	0.044*	0.025	1.77	0.006	-0.008	0.021	-0.37	-0.001	-0.060**	0.026	-2.29	-0.009	-0.044*	0.025	-1.78	-0.007
Household size	0.361**	0.153	2.36	0.047	0.688***	0.174	3.95	0.111	-0.026	0.154	-0.17	-0.004	-0.149	0.159	-0.94	-0.024
Monthly income	-0.320	0.566	-0.56	-0.042	0.482	0.518	0.93	0.078	1.626***	0.584	2.78	0.244	1.832***	0.547	3.35	0.295
Years of education	-0.125**	0.051	-2.44	-0.016	-0.134**	0.053	-2.54	-0.022	0.142***	0.054	2.65	0.021	-0.005	0.052	-0.09	-0.001
Location																
Rural	1.223***	0.455	2.69	0.170	0.263	0.410	0.64	0.042	-0.455	0.413	-1.10	-0.069	-0.747*	0.427	-1.75	-0.120
Type of dwelling																
Single room/self con.	-0.432	0.506	-0.85	-0.056	0.253	0.467	0.54	0.042	-0.610	0.456	-1.34	-0.094	-0.240	0.462	-0.52	-0.040
Traditional	0.963	0.765	1.26	0.144	1.594*	0.920	1.73	0.219	-1.154	0.758	-1.52	-0.185	-0.825	0.904	-0.91	-0.123
Poverty status	-0.276	0.523	-0.53	-0.036	-0.518	0.472	-1.1	-0.084	0.254	0.467	0.54	0.038	0.548	0.476	1.15	0.088
Closeness to energy source	-0.400	0.450	-0.89	-0.052	0.493	0.426	1.16	0.080	-0.122	0.421	-0.29	-0.018	-0.321	0.424	-0.76	-0.052
Complexity of device	0.319	0.668	0.48	0.042	-0.464	0.759	-0.61	-0.075	-0.871	0.719	-1.21	-0.131	-1.833	1.126	-1.63	-0.295
Constant	-0.053	5.903	-0.01		-5.762	5.274	-1.09		-15.280	5.956	-2.57		-17.576	5.520	-3.18	
Log Likelihood	**-74.22**				**-87.61**				**-83.35**				**-87.37**			
Observations	**180**				**180**				**180**				**180**			
LR chi^2(11)	**71.46**				**51.05**				**75.58**				**37.97**			
Prob>chi^2	**0.000**				**0.000**				**0.000**				**0.000**			
Pseudo R^2	**0.325**				**0.226**				**0.312**				**0.179**			

***, **, * *represent significance at 1%, 5% and 10% levels, respectively; s.e: standard error; dy/dx: marginal effects*

Table 7: Parameter estimates of the determinants of use of various energy types for lighting

	Coef.	s.e.	z	dy/dx	Coef.	s.e.	z	dy/dx	Coef.	s.e.	z	dy/dx	Coef.	s.e.	z	dy/dx
	Battery				**Petrol**				**Kerosene**				**Electricity**			
Sex																
Female	-0.161	0.359	-0.45	-0.031	-0.330	0.361	-0.91	-0.062	0.889**	0.378	2.35	0.153	0.968*	0.498	1.94	0.107
Age	0.018	0.021	0.87	0.003	-0.072***	0.023	-3.07	-0.013	-0.011	0.022	-0.50	-0.002	0.011	0.028	0.40	0.001
Household size	0.090	0.124	0.72	0.017	0.090	0.136	0.66	0.017	0.233*	0.131	1.77	0.038	-0.110	0.150	-0.73	-0.013
Monthly income	-0.490	0.457	-1.07	-0.094	1.757***	0.511	3.44	0.328	-0.213	0.498	-0.43	-0.035	1.927***	0.635	3.04	0.220
Years of education	-0.003	0.045	-0.06	-0.001	-0.062	0.046	-1.36	-0.012	-0.036	0.051	-0.71	-0.006	0.091	0.057	1.60	0.010
Location																
Rural	-0.793**	0.373	-2.12	-0.153	-0.013	0.374	-0.04	-0.002	-0.054	0.391	-0.14	-0.009	-0.620	0.466	-1.33	-0.072
Type of Dwelling																
Single room/self con.	1.254***	0.429	2.92	0.246	-0.852**	0.410	-2.08	-0.166	0.403	0.442	0.91	0.068	0.032	0.555	0.06	0.004
Traditional	1.229*	0.655	1.87	0.240	-0.789	0.679	-1.16	-0.154	1.336*	0.702	1.90	0.239	-1.176	0.774	-1.52	-0.158
Poverty status	-0.363	0.452	-0.80	-0.069	-0.269	0.426	-0.63	-0.050	1.407***	0.437	3.22	0.231	-1.359***	0.576	-2.36	-0.156
Closeness to energy source	-0.769**	0.368	-2.09	-0.147	0.482	0.375	1.29	0.090	-0.051	0.406	-0.13	-0.008	0.037	0.493	0.07	0.004
Complexity of device	-0.543	0.675	-0.80	-0.104	-0.529	0.649	-0.81	-0.099	0.183	0.665	0.27	0.030	-1.148	0.752	-1.53	-0.131
Constant	3.748	4.728	0.79		-14.798	5.158	-2.87		0.131	5.140	0.03		-19.109	6.665	-2.87	
Log likelihood	**-101.54**				**-99.17**				**-89.98**				**-65.18**			
Observations	**180**				**180**				**180**				**180**			
LR $chi^2(11)$	**32.38**				**51.10**				**56.63**				**62.81**			
Prob > chi^2	**0.001**				**0.000**				**0.000**				**0.000**			
Pseudo R^2	**0.138**				**0.205**				**0.239**				**0.325**			

***, **, * *represent significance at 1%, 5% and 10% levels, respectively; s.e: standard error; dy/dx: marginal effects*

5. Conclusion and Recommendation

The study examined the relationship among fuel type choices for cooking and lighting together with the determinants of household energy choices in Ibadan. Firewood and charcoal were found to be in use as substitute cooking fuels to LPG while electricity was used as its complement. Improved economic and welfare states of households was found to be generally associated with the use of clean energy sources, in line with Ateba *et al.* (2018). Household with large number of members had to settle for less clean fuel types probably because of low per capita resource availability. Having well-educated household head assisted in making better fuel choices for cooking. However, poverty status was not associated with the cooking fuel choices. This could be due in part to availability of varying fuel types from which households could choose whichever is affordable. Living in the rural areas was also linked with increased probability of using firewood for cooking.

Several recommendations are put forward based on the results. There is need to implement policies aimed at putting more money in the pockets of the citizens, accompanied with other infrastructural and social services that will assist in making better fuel choices. More needed to be done in the efforts at better education delivery in addition to proper sensitisation of the masses on the health and environmental implications of using the different fuel types. Rural development efforts of the government should also be stepped up to aid in cleaner fuel choices by households in the rural areas.

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